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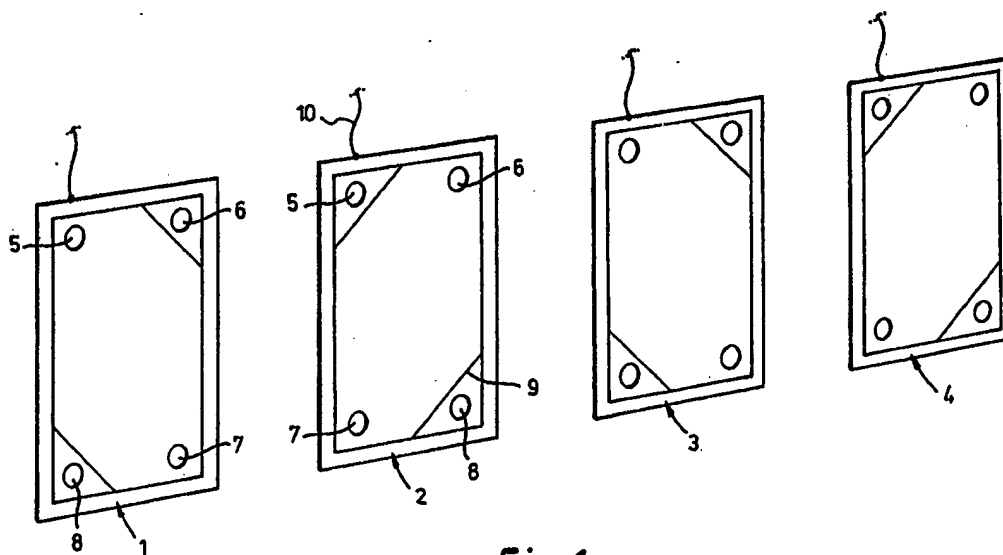
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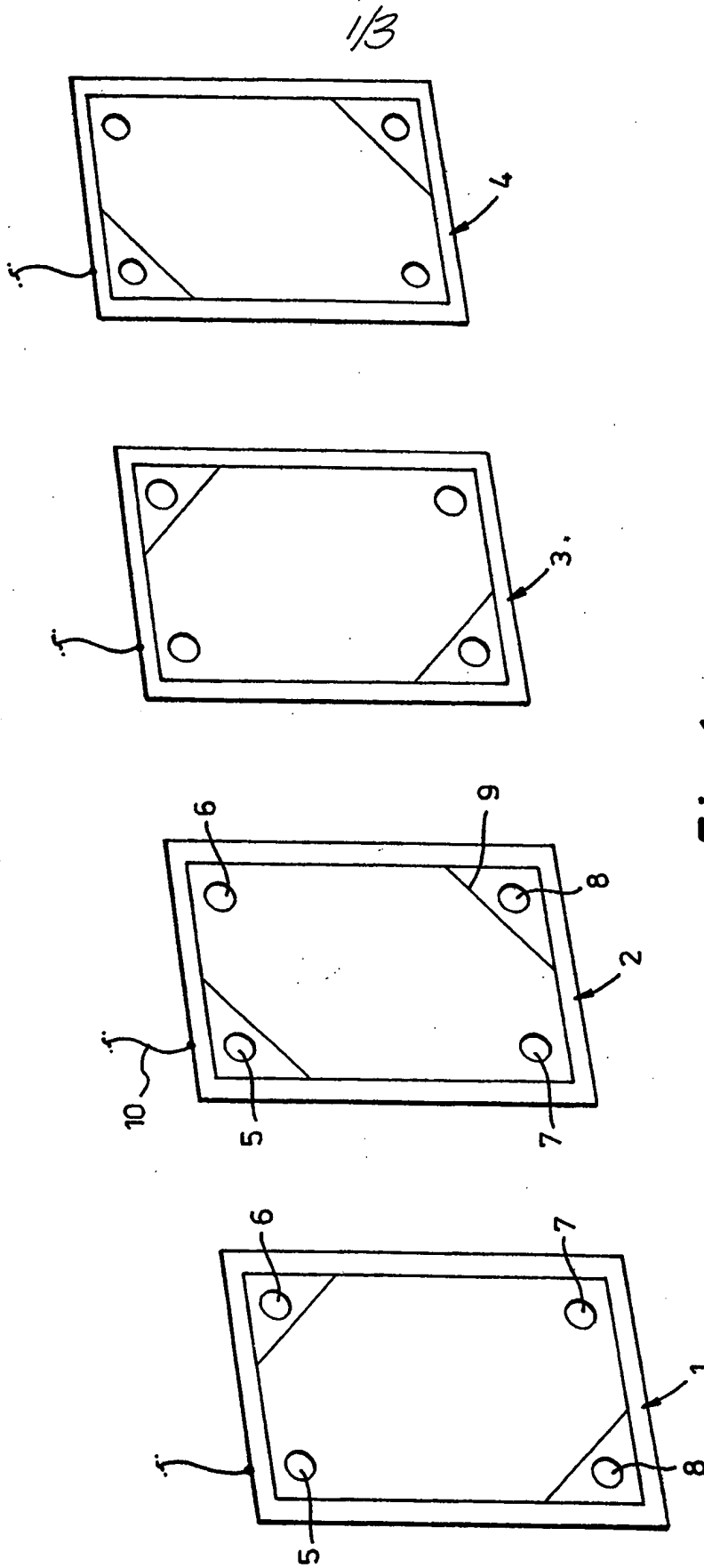
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(54) Heat exchangers

(57) Heat Exchangers and method for controlling fouling of heat exchanger surfaces in contact with process fluids in which electrical current is supplied to heat exchanger surfaces to convert these into electrodes. The invention also relates to plant and processes (particularly for the production of a single cell protein) incorporating the heat exchangers or method.

*Fig. 1.***GB 2 101 731 A**



2/3

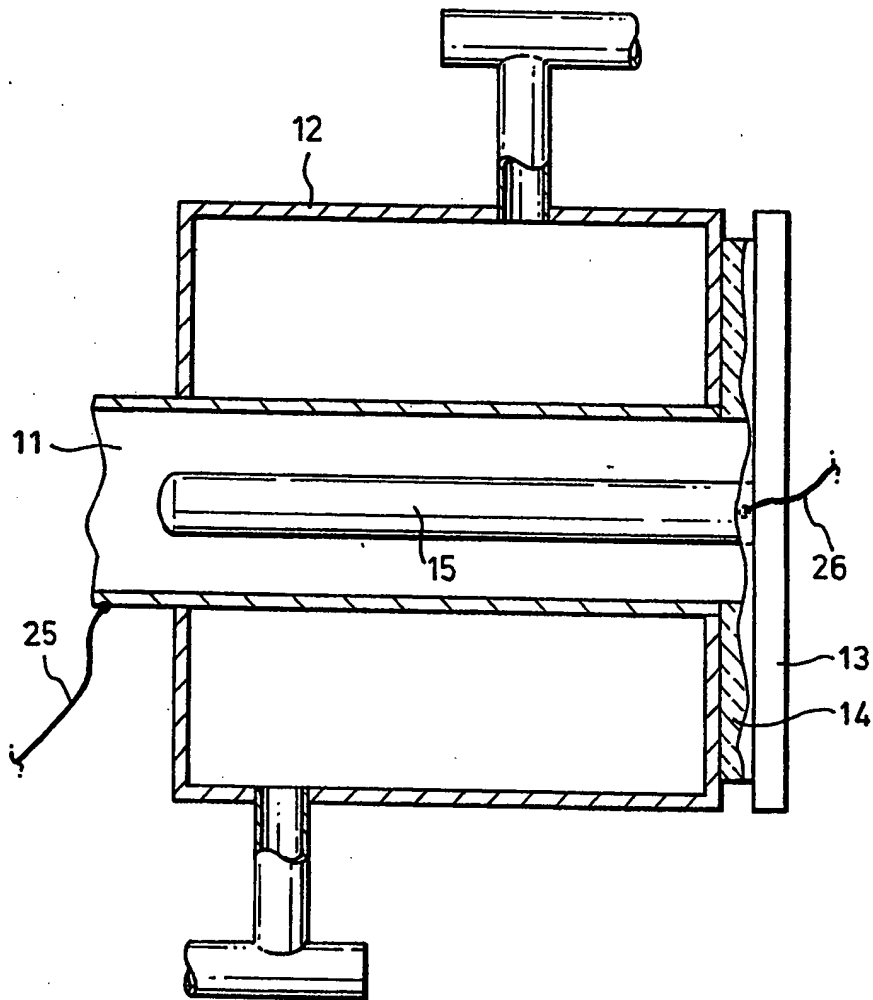


Fig.2.

3/3

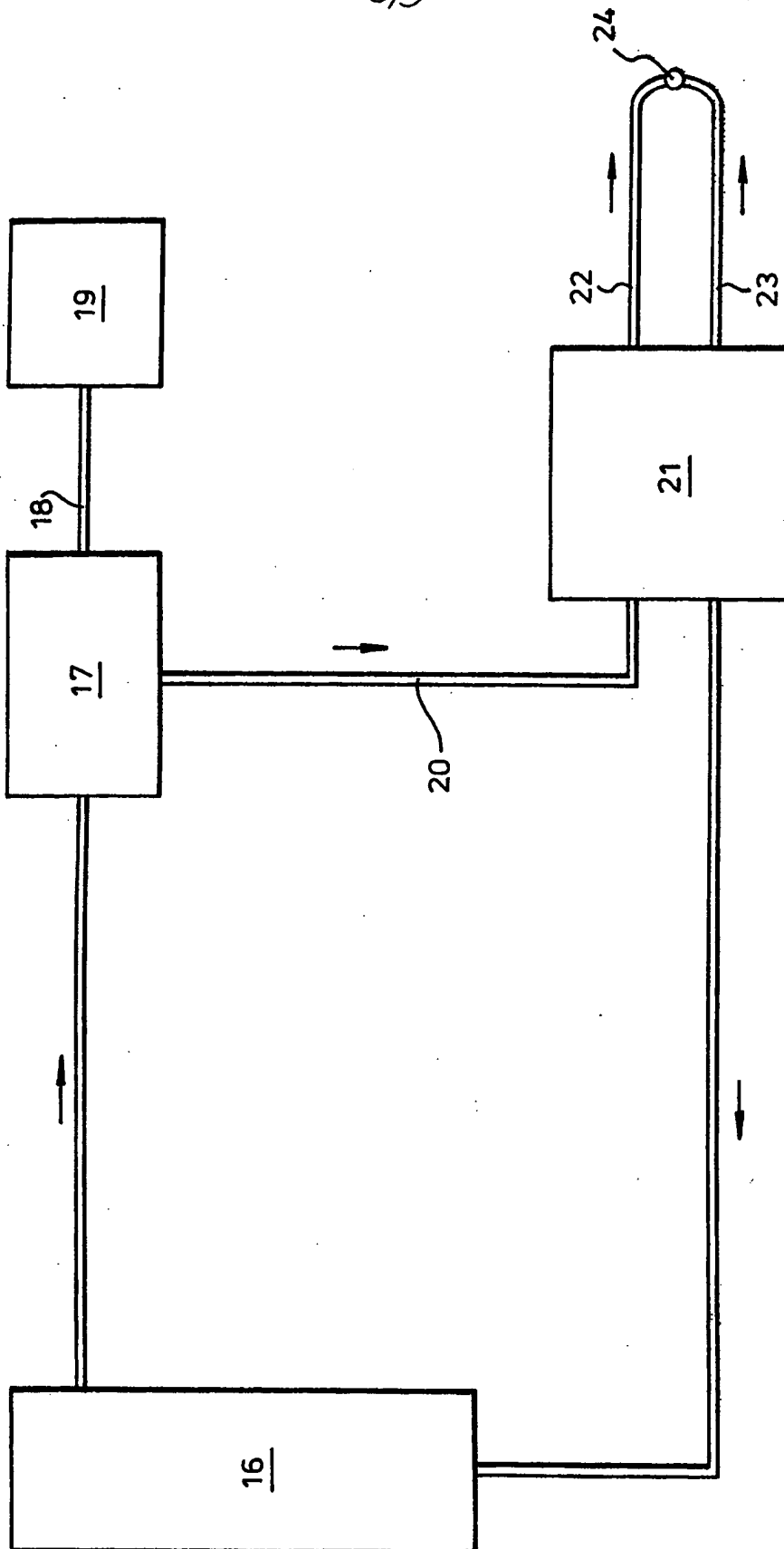


Fig. 3.

SPECIFICATION

Heat exchangers

5 This invention relates to heat exchangers, to a method for controlling fouling of heat exchanger surfaces in contact with process fluids and to plant and processes using the heat exchangers and method, particularly plant and processes for the production of single cell protein (SCP).

10 In certain processes, conducted in plant comprising heat exchangers, heat exchanger surfaces are in contact with process fluids which contain suspended solids and/or other materials which adhere to the surfaces to form a layer of material thereon which reduces the heat transfer coefficient and increases the pressure drop at the surfaces. Such processes include fermentation processes and in particular processes for the production of SCP. In fermentation processes fouling of heat exchanger surfaces is caused by proteins, polymeric compounds, cells, cell debris, organic compounds such as fatty acids and amino acids which are by-products of cell growth and which come out of solution in the heat exchangers and other materials. These materials adhere to the surfaces to form layers of material thereon which gradually increase in thickness until it is necessary to clean the heat exchangers. Such fouling causes considerable problems, particularly in system where maintenance of sterility is important. It is desirable that a method for the on-line control of fouling of heat exchanger surfaces is developed for use in such systems.

According to the present invention we provide a heat exchanger which comprises a first conducting surface which is an integral part of the heat exchanger, a first connecting means for connecting the first conducting surface to a source of electricity to convert it into a first electrode, a second conducting surface which is an integral part of the heat exchanger or is a part added to the heat exchanger and a second connecting means for connecting the second conducting surface to the electricity source to form a second electrode, connection of the first and second connecting means to the electricity source enabling a potential difference to be applied between the first and second electrodes.

Further according to the present invention we provide a method for controlling fouling of heat exchanger surfaces in contact with process fluids wherein an electrical current is supplied to a first conducting surface in a heat exchanger to convert the first surface into a first electrode and to produce a potential difference between the first electrode and a second electrode (which may be a second conducting surface in the heat exchanger) and thereby to reduce and/or control the amount of material deposited upon the first surface from a fluid in contact with that surface. Where the second electrode is formed by a second conducting surface in the heat exchanger the method can also reduce and/or control the amount of material deposited upon the second surface.

Further according to the present invention we provide a plant which includes a heat exchanger

wherein the heat exchanger comprises a first conducting surface which is an integral part of the heat exchanger, a first connecting means for connecting the first conducting surface to a source of electricity to convert it into a first electrode, a second conducting surface which is an integral part of the heat exchanger or is a part added to the heat exchanger and a second connecting means for connecting the second conducting surface to the electricity source to form a second electrode, connection of the first and second connecting means to the electricity source enabling a potential difference to be applied between the first and second electrodes.

Further according to the present invention we provide in a process in which an electrically conducting process fluid contacts an electrically conducting heat exchanger surface, the improvement which comprises on-line control of fouling of the heat exchanger surface in contact with the process fluid by supplying an electrical current to a first conducting heat exchanger surface to convert the first surface into a first electrode and to produce a potential difference between the first electrode and a second electrode (which may be a second conducting surface in the heat exchanger) and thereby reducing and/or controlling the amount of material deposited upon the first surface from process fluid in contact with that surface.

The present invention may be applied to any type of heat exchanger. In its application to plate heat exchangers many variations are possible in the mode in which electrical current is supplied to the plates. For instance current can be supplied only to plates at the extreme ends of the bank of plates or it can be supplied to every plate. In either of these cases the effect is to create electrical cells throughout the heat exchanger. Alternatively current can be supplied only to plates in one or more sections of the heat exchanger which are subjected to the worst fouling during use. When the invention is applied to shell and tube or jacketed tube heat exchangers it is useful to make a wall of the heat exchanger into one electrode and to use, e.g. a metal rod, inserted into the heat exchanger as the second electrode, i.e. a counter electrode.

The present invention is useful in processes and plant for fermentation, particularly processes and plant for the production of single cell protein (SCP). Fermentation processes usually require heat exchangers, the internal surfaces of which are constantly in contact with process liquids containing a variety of materials, such as those mentioned above, which can adhere to the heat exchanger surfaces causing fouling and a consequent reduction in efficiency. In process for the production of SCP where there is a sterile recycle of aqueous culture medium to a fermenter severe fouling problems can occur in heat exchangers in the sterile recycle line. The method of the invention is usefully applied to heat exchangers in this invention.

In the method of the invention application of electrical current with a sufficient potential difference between heat exchanger surfaces produces an evolution of gas at the surfaces which causes deposits of solid material on the surfaces to fall off

into the process fluid and to be carried away thereby. The method is suitably operated for such periods that only thin layers of material are present on the heat exchanger surfaces at any time. How this is achieved will depend upon the rate at which fouling of the surfaces is occurring, e.g. upon the nature of the material being deposited and upon the rate at which it is being deposited upon the surfaces. Current can be applied to the surfaces at all times during the process but this could prove to be expensive.

Hence it is preferable that current is supplied only for periods, especially periods spaced at regular intervals, sufficient to ensure that only a thin layer of material is deposited on the surfaces. For instance in some processes current may only be applied for one 10 minute period every 12 hours. Preferably the process fluid is a conducting liquid, e.g. an aqueous medium having a pH within the range 2 to 5 and particularly 3.5.

The electrical current is preferably supplied to the surfaces at a density of 10 – 100 milliamps/cm², especially 25 to 50 milliamps/cm². The current may be AC or DC, the latter being preferred. Current may be supplied continuously or in pulses. The manner in which the current is supplied, i.e. if a particular surface is an anode or a cathode, is a matter of choice depending upon individual circumstances. It is preferred however that surfaces most in need of cleaning or, where a counter electrode is used, the surface of the jacketed tube or of the shell tube heat exchanger is the cathode.

The materials from which the heat exchanger surfaces and any counter electrodes are constructed are chosen depending upon the pH, and temperature of the process fluid and also to some extent upon inorganic materials present in the fluid. Preferably the materials are selected from those least likely to be corroded under the conditions of use, e.g. stainless steel. A particularly useful combination is an Incolloy 825 cathode and a titanium anode.

The invention is illustrated by the accompanying drawings wherein:-

Figure 1 is an exploded diagram of a part of a plate heat exchanger according to the invention;

Figure 2 is a cross-sectional elevation of a jacketed tube heat exchanger according to the invention;

Figure 3 is a schematic diagram of a plant for the production of single cell protein (SCP) having a heat exchanger according to the invention.

Figure 1 shows four plates 1, 2, 3 and 4 from a plate heat exchanger which has a total of 100 plates. The plates are corrugated although the corrugations are not shown in the drawing. In the assembled heat exchanger the plates are held together, each one being in close proximity to its immediate neighbours, between two end plates connected by bars. The plates are electrically insulated from each other by rubber strips positioned at points of contact. Each plate contains four orifices 5, 6, 7 and 8. Through two of these, 5 and 7, there passes a process liquid to be cooled and through the others, 6 and 8, passes cooling water. Suitably positioned rubber barriers such as 9 ensure that process liquid and cooling water flow across alternate plates, i.e. process liquid flows across plates 1 and 3 and cooling water across

plates 2 and 4. Each plate is fitted with a terminal to which is attached a connecting means, such as wire 10 on plate 2, which can be connected to an electricity source (not shown in the drawing). The plates are connected in pairs to electricity sources to form electric cells. Thus plates 1 and 2 are connected to one source to form one cell and plates 3 and 4 are connected to another source to form a second cell.

Figure 2 shows in cross-section a jacketed tube heat exchanger having a tube 11, through which can pass a process liquid, encircled by a water jacket 12. At one end of tube 12 is a perforated flange 13 through whose perforations the process fluid can pass. Insulating layer 14 separate flange 13 from water jacket 12. Tube 11 is formed from stainless steel and has attached to it an electrical connecting means 25 which connects it to a source of electricity (not shown in the drawing) in such a way that tube 11 becomes the cathode of an electric cell. The anode of the cell is titanium rod 15 (a counter anode) which is connected to the electricity source through connecting means 26.

Figure 3 shows a plant for the production of single cell protein (SCP) in which a micro-organism, such as a bacterium, is grown continuously upon a nutrient medium containing inter alia a carbon source, such as methanol in a fermenter 16. The process may be that of UK Patent 1370892 and the fermenter that of UK Patent 1353008. Culture is continuously removed from fermenter 16 and subjected to various treatment steps including a separation step in centrifuge 17 from which a thick "cream" containing suspended cells passes along path 18 to drier 19 to give SCP product, whilst separated medium passes along path 20 to heat exchanger 21. The separated medium is to be returned to fermenter 16 under sterile conditions and for this purpose its temperature is raised to 135°C by steam injection at 24. The heated medium enters heat exchanger 21 along path 23, being cooled to 115°C during its passage through heat exchanger 21. During its passage through heat exchanger 21 however the heated medium heats up the medium which enters heat exchanger 21 along path 20 and leaves along path 22 from 90°C to 110°C. The medium contains cell debris and by-products of cell growth such as fatty acids and organic compounds which tend to come out of suspension or solution in the heat exchanger forming a deposit of material on the surfaces thereof. When the heat exchanger is a shell and tube heat exchanger equipped with a counter electrode and with appropriate connections to an electrical supply in accordance with the invention the extent of fouling in heat exchanger 21 may be controlled on-line during operation of the process. This avoids the problems attendant upon changing heat exchangers periodically in a sterile system.

CLAIMS

1. A heat exchanger which comprises a first conducting surface which is an integral part of the heat exchanger, a first connecting means for connecting the first conducting surface to a source of electricity to convert it into a first electrode, a second conducting surface which is an integral part of the heat exchanger or is a part added to the heat exchanger

and a second connecting means for connecting the second conducting surface to the electricity source to form a second electrode, connection of the first and second connecting means to the electricity source enabling a potential difference to be applied between the first and second electrodes.

2. A heat exchanger according to claim 1 wherein the second conducting surface is an integral part of the heat exchanger and the first and second conducting surfaces are plates.

3. A heat exchanger according to claim 2 wherein the first and second conducting surfaces are constructed from stainless steel.

4. A method for controlling fouling of heat exchanger surfaces in contact with process fluids wherein an electrical current is supplied to a first conducting surface in a heat exchanger to convert the first surface into a first electrode and to produce a potential difference between the first electrode and a second electrode and thereby to reduce and/or control the amount of material deposited upon the first surface from a fluid in contact with that surface.

5. A method according to claim 4 wherein the second electrode is a second conducting surface in the heat exchanger.

6. A method according to claim 5 wherein the first and second conducting surfaces are plates.

7. A method according to claim 6 wherein electrical current is supplied to plates in one or more sections of a plate heat exchanger and not to a remaining section or sections of the heat exchanger.

8. A method according to any one of claims 4 to 7 wherein electrical current is supplied to the surfaces at a density of 10–100 milliamps/cm².

9. A method according to any one of claims 4 to 8 wherein the electrical current supplied to the surfaces is DC current.

10. A plant which includes a heat exchanger wherein the heat exchanger comprises a first conducting surface which is an integral part of the heat exchanger, a first connecting means for connecting the first conducting surface to a source of electricity to convert it into a first electrode, a second conducting surface which is an integral part of the heat exchanger or is a part added to the heat exchanger and a second connecting means for connecting the second conducting surface to the electricity source to form a second electrode, connection of the first and second connecting means to the electricity source enabling a potential difference to be applied between the first and second electrodes.

11. A plant according to claim 10 for the production of single cell protein in which there is a sterile recycle line for the return of aqueous culture medium to a fermenter and the heat exchanger is located in the recycle line.

12. In a process in which an electrically conducting process fluid contacts an electrically conducting heat exchanger surface, the improvement which comprises on-line control of fouling of the heat exchanger surface in contact with the process fluid by supplying an electrical current to a first conducting heat exchanger surface to convert the first surface into a first electrode and to produce a potential difference between the first electrode and a second

electrode and thereby reducing and/or controlling the amount of material deposited upon the first surface from process fluid in contact with that surface.

13. A process improvement according to claim 12 wherein the second electrode is a second conducting surface in the heat exchanger.

14. A process improvement according to claim 12 or claim 13 applied to a process for producing single cell protein in which there is a sterile recycle line for the return of aqueous culture medium to a fermenter and the heat exchanger is located in the recycle line.

15. A heat exchanger substantially as described and as shown in Figures 1 and 2 of the accompanying drawings.

16. A method for controlling fouling of heat exchanger surfaces in contact with process fluids substantially as described and as shown in Figures 1 and 2 of the accompanying drawings.

17. A plant for the production of single cell protein including a heat exchanger substantially as described and as shown in Figure 3 of the accompanying drawings.

18. An improvement in a process for the production of single cell protein substantially as described and as shown in Figure 3 of the accompanying drawings.

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